CHAPTER 1
INTRODUCTION

Currently, new expendable launch vehicles (ELVs) are being designed with numerous improvements over existing technologies. Future generation launch vehicles need to be able to launch heavier payloads for a given rocket size and fuel consumption. The major cause for the increase in payload weight capability is attributed to more powerful engines, optimized structural designs, and lighter materials.

Traditionally payload fairings have been constructed from lightweight aluminum alloys. However, designers are currently developing composite fairing which are much easier to manufacture while also being lighter and stiffer than existing aluminum fairings. The new fairings are expected to be designed from composite materials using either a sandwich, monocoque, isogrid, or an advanced grid stiffened structural design (Shen and Pope, 1990, Robinson et al., 1991, Huybrechts and Meink, 1997).

Payload fairings (PFs) are initially designed to satisfy the structural loading requirements induced during launch (i.e. buckling). Once a satisfactory structural design has been created, the fairing is then redesigned to consider the acoustic loading. Reducing the acoustic noise the payload (i.e. satellite) receives during launch has always been an important design constraint. An excess of acoustic noise transmitted through the fairing poses a potential threat to the life of the payload. Since future fairings will be constructed of lighter materials having a lower transmission loss (TL), the acoustic threat is even more severe.

Traditionally acoustic blankets, lining the fairing wall, have been used to absorb acoustic energy and convert it to heat. However the blankets are not effective in the lower frequency range, below 400Hz. Active control technology is currently being investigated as a potential solution to reduce the sound pressure levels (SPLs) within the fairing for this frequency range. The overall solution needs to be lightweight, relatively inexpensive, small in size, and not draw a significant amount of power, while having the authority to reduce the fairing interior sound pressure levels (SPLs).

One actuator, which is presently considered a strong candidate, is the piezoelectric (PZT) actuator. It is being considered because of its small size, actuating bandwidth, and because it can be easily embedded or mounted onto a composite fairing. However, the ability of PZT actuators to control the fairing internal SPLs has not yet been determined. To help determine the acoustic control authority of PZT actuators mounted onto fairing like structures, the internal acoustic response created by these actuators needs to be determined. This chapter will give the reader an understanding of the scope of the fairing acoustical problem and will show how this work will assist in providing insight in determining the feasibility of using PZT actuators on payload fairings.

1.1 The Acoustic Disturbance and Some Solutions

The severe acoustics during a launch occur at liftoff, transonic, and maximum dynamic pressure (Long, et al., 1996). For most ELVs the highest acoustic loading occurs at liftoff (Kahre, 1990, Himelblau, et al., 1992). The source of the acoustic noise provided to the payload fairing (PF) at liftoff originates from the burn of the rocket engines during launch as shown in Fig. 1.1 (Bourgine et al., 1979). The primary acoustic noise is reflected from the launch pad at liftoff. The launch pad size, geometry, and elevation of the rocket above the launch pad play a crucial role in reducing the overall sound pressure level at the payload fairing. Several methods to reduce the acoustic environment during liftoff include (Eldred, 1971):

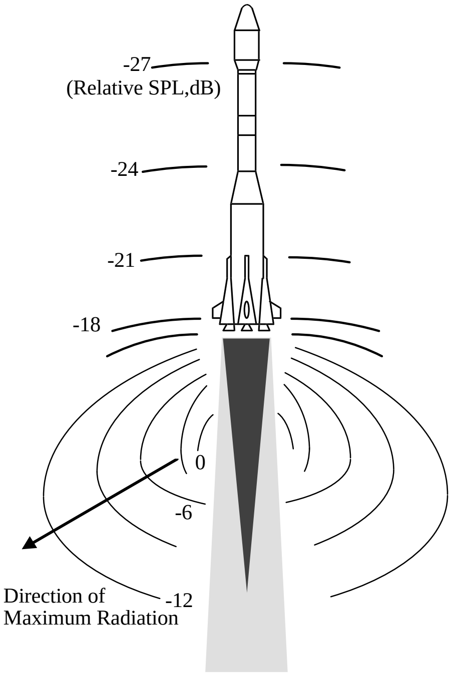
a. The thrust deflection angle should be kept as small as possible.
b. The exhaust flow should be deflected through a “covered bucket” or tunnel.
c. Water should be injected into the deflector near the nozzle.

The increase in external SPL as the rocket reaches transonic speeds is caused by an external fluctuating pressure generated by flow separation around the shoulder of the rocket (local normal shock wave which appears on the cylinder) (Fukushima, et al.,1992). Typical values of internal and external SPLs range from 120 to more than 150 dB and are shown in Fig. 1.2 for a Titan IV rocket (Elliot, 1990, Bergen and Kern, 1996, Himelblau, et al., 1992). Two interesting things should be noted about the acoustic environment within the fairing during launch. The SPLs are extremely high and the frequency content is broadband and nondeterministic. This magnifies the difficulty in controlling the internal acoustics using active control.

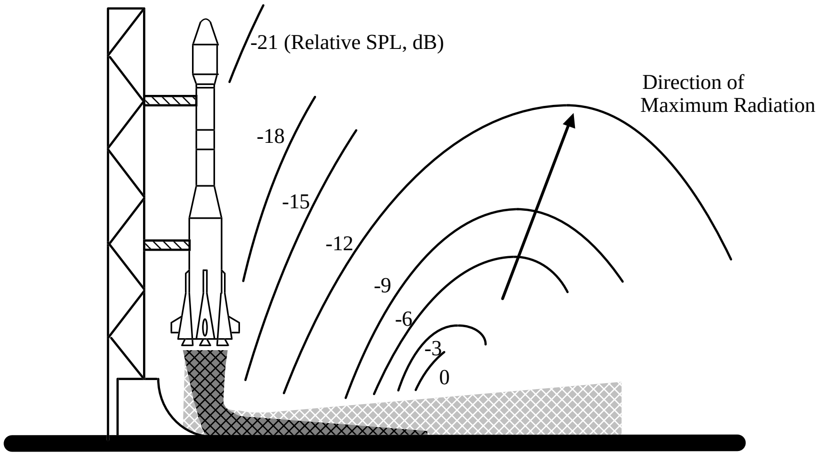
Today’s fairing designers employ two classical noise control techniques. The first implements blocking and is done by adding mass to the fairing wall to increase the overall insertion loss (IL). This is generally dependent on the fairing mass density, excitation frequency, and particular structural design. The second technique implements acoustically absorbing blankets. The absorption coefficient is mainly dependent on the type of material, thickness, and excitation frequency. The absorption coefficient for a typical fairing can be represented as increasing proportionally with frequency below the peak frequency and decreasing with the inverse of frequency above the peak frequency as shown in Fig. 1.3 (Weissman, et al., 1994). Experimental results have shown that acoustic blankets are not effective for attenuating acoustical noise with frequency content less than 300-400 Hz as shown in Fig. 1.4 (Lee, 1992). A recent study on a variety of acoustic blankets was performed for the Cassini spacecraft. The blanket that was chosen was a 6 in. thick blanket with a mass density of 0.8 lbs/ft^2 (Bradford and Manning, 1996).

The idea of purging the air within the fairing with helium to reduce the internal SPL was investigated. Experimental results showed the interior SPL was reduced by approximately 10 dB throughout the spectrum. However, the payload random vibration was found to increase in some panels and decrease in others. The conclusion reached by the investigators was that even though the SPL was reduced, the damping of the payload structure was also reduced due to a decrease in the gas pumping effect of the payload joints. Analysis shows that a helium medium causes a more severe environment for the structure (Lee, 1988, Eaton and Betti, 1996).

The use of damping material attached to a typical fairing isogrid composite panel has also been investigated, however research in this area is continuing (Drake et al.,1993). Bergen investigated using tuned vibration absorbers on the Cassini spacecraft to attenuate the vibration of the primary structure and protect the attached hardware (Bergen, 1995). The performance of the vibration absorbers was compared to the implementation of improved Titan IV payload fairing acoustic blankets. In general the blankets caused a greater reduction in vibration and provided a global reduction in the spacecraft vibration, while the vibration absorbers only provided a localized effect. The vibration absorbers were also only effective in a narrow frequency range while the blankets produced a broadband effect. Ultimately, the blankets were implemented (Bergen and Kern, 1996).



a. In flight



b. During Liftoff

Figure 1.1 Contour of equal overall SPL (Eldred, 1971).

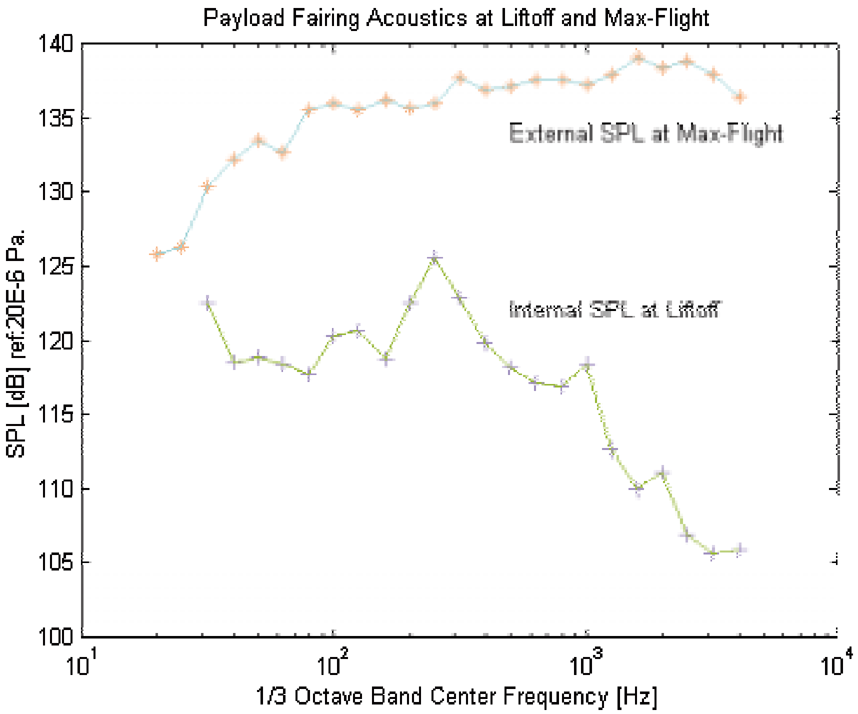


Figure 1.2 Titan IV rocket fairing SPLs (Elliot, 1990).

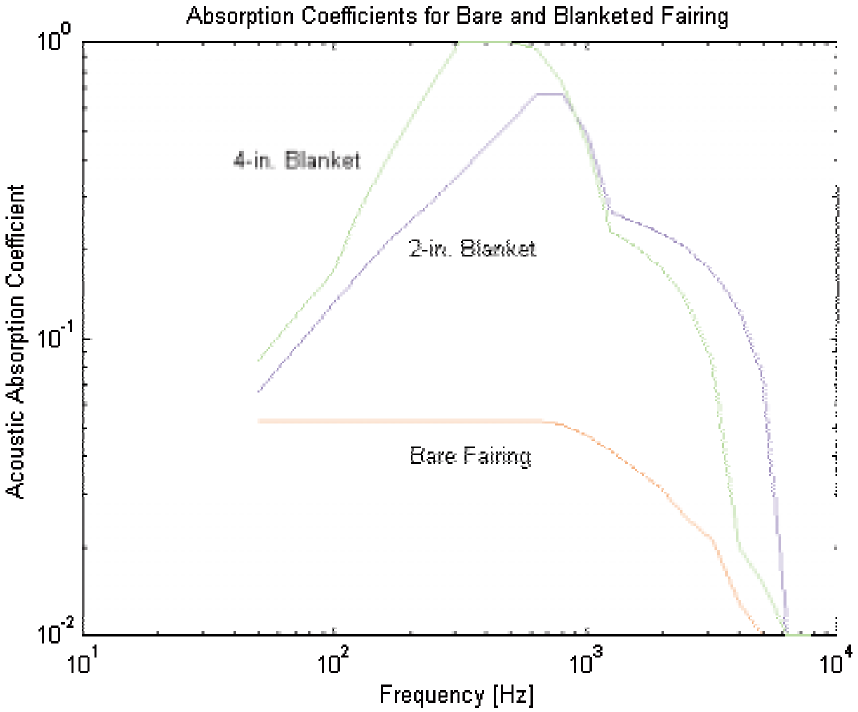


Figure 1.3 Typical absorption coefficients for a fairing (Weissman, et al., 1994).

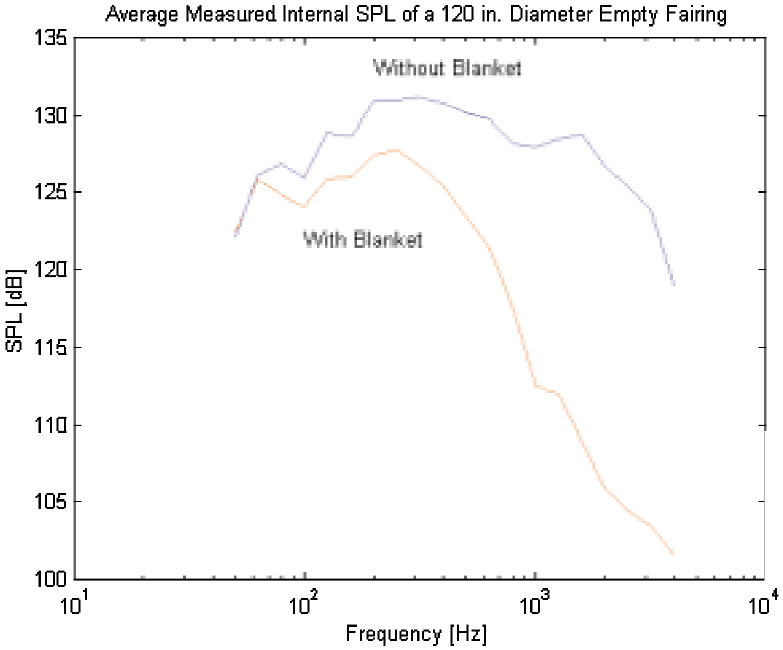


Figure 1.4 Effect of blankets on internal SPL (Lee, 1992).

1.2 Motivation and Requirements for Active Control of Payload Fairings

Because the acoustic blankets are not effective below 300-400 Hz (Lee, 1992) it is hopeful that active control will be able to significantly reduce the internal SPLs of payload fairings (PFs). Presently, no robust solution exists to control the low frequency sound internal to PFs during launch. Several requirements must be satisfied for an active control system to be implemented in order to control PF vibrations and internal acoustics. In general the overall control system needs to have the following characteristics:

a. The entire control system can not be a significant weight burden to the PF design.
b. The control system must be sufficiently robust to survive the severe launch environment.
c. The controller must be able to control the broadband nature of the disturbance (frequency content between 30 and 400 Hz).
d. Implementation of a feedforward controller is not practical since the disturbance is nondeterministic.
e. The control system must be able to function effectively regardless of the orientation of the disturbance.
f. The entire control system must be contained within a few inches of the fairing wall.
g. The actuators need to have sufficient authority to be able to control the internal PF acoustics.
h. The control system can not draw significant amounts of power or current from the launch vehicle.

In this work, only requirements g and h will addressed.

1.3 Active Structural/Acoustic Control

In the last two decades, a great deal of work has been performed on the control of structural vibrations and acoustics. For 1-D (i.e. ducts), the application of this technique has been used effectively for single tones and broadband noise (Kazakia, 1986, Roure, 1985, Warnaka, 1982, Ross, 1982). Spatial control of three dimensional acoustic fields is much more difficult. Theoretically a Huygen surface (see Fig. 1.5) can be created and the sound at every point within the surface can be reduced to zero. Physically, the Huygen surface is not realistic and approximations have to be made (Stevens and Ahuja, 1991).

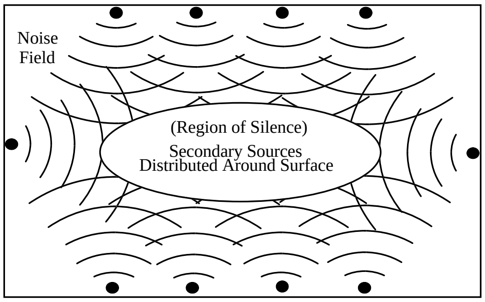


Figure 1.5 Huygen’s Surface: Secondary Sources Produce a Region of Silence (Stevens and Ahuja, 1991)

Active acoustic control generally implements acoustic control sources (speakers) to achieve sound attenuation. Two control mechanisms are present: acoustic power suppression and acoustic power absorption. For suppression, the control source is used to unload the disturbance or primary source (effectively changing its acoustic impedance) and so the acoustic power output from the primary source is reduced. For absorption, the control source is used to absorb (or cancel) the acoustic power from the primary source (Snyder and Hansen, 1994). Several authors have demonstrated active noise control within cylindrical structures using acoustic control sources (Silcox, et al., 1990, Elliot, et al., 1990, Silcox, et al., 1989, Lester and Fuller, 1987). From a practical perspective, it is often difficult to position the secondary sources and microphones away from the structure. This is the case for a payload fairing where the control sensors and actuators are restricted to the space close to the fairing wall. Also, acoustic control sources generally produce additional unwanted noise and can create a condition called “control spillover”; especially when a robust model of the system to be controlled does not exist. (Hesseleman, 1978, Fuller, et al., 1989, Fuller, 1988).

One major drawback of using this technique in the low frequency range is the space requirement. For a simple monopole acoustic source, the pressure as a function of radial distance and time is given by:

$$p(r,t) = \frac{V_o \rho c}{\left\{1 - \frac{i}{ka}\right\}} \frac{a}{r} e^{i(\omega t - k(r-a))} \tag{1.1}$$

where a is the radius of the source, k is the wavenumber, i is an imaginary number, ω, V_o, and ρc are the angular frequency, velocity amplitude, and characteristic impedance of the medium, respectively. When pressure and velocity are ninety degrees out of phase no acoustic energy is transmitted. Likewise, to be an efficient radiator of sound, ka should be greater than 10, or the radius of the source should be larger than approximately twice the wavelength. Clearly as the excitation frequency is lowered the acoustic wavelength is increased. For a frequency of 300 Hz, the wavelength of sound is 1.13 meters. Monopoles are not as effective as audio speakers in generating sound, however the fundamental principles still apply and for frequencies less than 300 Hz, large diameter audio woofers would be required. Unfortunately, the space requirements within the fairing limit the size of the active control actuator to within 4-5 inches of the fairing skin. The space within the fairing is reserved for the payload.

Instead of using acoustic control sources, a relatively new technique has been investigated which reduces the noise radiated from vibrating structures by actively controlling the structure. This is performed by actively altering the spatial velocity distribution of the structure. Typically this can be achieved by exciting the structure using proof mass, PZT, or other actuators mounted onto the structure. This technique is commonly referred to as active structural acoustic control (ASAC). Two control mechanisms are present: modal suppression and modal restructuring or rearrangement (Clark and Fuller, 1991, Lefebvre, 1991). For suppression, the amplitudes of the dominantly radiating structural modes are reduced. For restructuring (or rearrangement), the control system actively changes the magnitude and phase of the acoustically coupled structural modes. This reduces the overall acoustic response, but may cause the structural vibration amplitudes to increase. For an enclosed space, modal restructuring is effective because there are multiple structural modes, having similar magnitude, coupled into a single acoustic mode. Acoustic control by modal restructuring is not possible if there is only a single structural mode exciting a given acoustic mode (Snyder and Hansen, 1994). Many authors have applied ASAC on plates (Maillard and Fuller, 1995, Mathur et al., 1995, Wang et al., 1994, Koshigoe et al., 1993, Clark and Fuller, 1992, Clark and Fuller, 1991b) and on cylindrical type structures (Fuller and Gibbs, 1994, Lester and Silcox, 1992, Sonti and Jones, 1991, Silcox et al., 1990, Fuller and Jones, 1987, Sumali, 1992). One of the drawbacks to using point forces (shakers and proof mass actuators) is the control spillover caused by the "spectrally white" actuation. The point forces can couple into all structural modes and cause control spillover (Fuller et al., 1989). This effect is important especially if the system to be controlled does not have a comprehensive model, as is the case for payload fairing. These types of actuators also tend to be heavy and have mounting difficulties, which makes their application to launch vehicles difficult.

As a rule of thumb, it is generally considered that acoustic control sources are better at controlling acoustic resonances, while vibration control inputs are better suited to attenuate structural resonances (Snyder and Hansen, 1994). It has also been shown that active acoustic control using vibration inputs or acoustic control sources is sensitive to the control actuator and sensor location (Silcox, et al., 1990, Silcox et al. 1989). Unfortunately, the fairing disturbance does not have a specific orientation and excites the structure in a broadband frequency range. This presents a significant challenge to any control system used to attenuate fairing vibrations and internal acoustics due to the additional number of modes to be controlled increasing the complexity of the controller.

1.4 Active Control Research Related to Payload Fairings

It is hopeful that active control will be able to significantly reduce the internal SPLs for fairings in the low frequency range (30-400Hz). Only within the last several years has work been performed specifically in relation to the active control of PFs. Koshigoe et al. initially investigated a new technique for controlling noise transmission into a cavity using piezoelectric actuators on an elastic plate effective for both plate and cavity modes. They concluded that sensing plate motion is only effective on plate controlled modes and that if sensing is based on pressure, both cavity and plate modes can be suppressed using PZT actuators (Koshigoe et al., 1993). Falangas et al. studied how PZT actuators can be used to control plate vibrations using H_∞ and rate feedback (Falangas et al., 1994, Falangas et al., 1993). It was found that the performance of the H_∞ controller was significantly superior to the rate feedback controller in their experiment. Koshigoe et al. developed a time domain model for simulating the noise transmission through an elastic plate into a rigid cavity using a filtered-x least mean square (LMS) controller and PZT actuators. They concluded that a decrease in the mean air density reduces the sound transmission and stabilizes the controller. This implies that controlling the sound transmission through a fairing wall is easier at the maximum dynamic pressure flight stage compared to the liftoff stage of launch (Koshigoe et al., 1995). Koshigoe et al. also created an adaptive control algorithm with on-line system identification capability (Koshigoe et al., 1995b).

Niezrecki and Cudney provided a description of the payload fairing acoustic problem, possible solutions, and evaluated potential actuation schemes for active control (Niezrecki and Cudney, 1996). Houston et al. numerically modeled a fairing structure and the internal space using finite element analysis. Their analysis indicates that the interior acoustic response of the fairing is dominated by normal modes of the acoustic cavity. They also numerically investigated the use of active control sources and active blankets to control the internal acoustics. The results were encouraging (Houston et al., 1996, Houston et al., 1997). Newbury et al. performed an experimental/numerical analysis to determine the dynamic properties of an advanced grid stiffened composite plate. They also determined the acoustic radiating properties of the plate and showed that piezoelectric actuators were effective in exciting and sensing the dominant radiating modes (Newbury et al., 1998). Denoyer et al. experimentally controlled the structural and cavity modes of a sub-scale composite isogrid payload fairing using piezoelectric actuators and acoustical control sources and several second-order positive position feedback controllers. It was observed that the dominant acoustic modes were not controllable using structural control while the acoustic control sources had little effect on the acoustic field excited by the structural modes (Denoyer et al., 1998). Glaese and Anderson modeled a full scale composite payload fairing (STARS fairing). They experimentally performed a modal and acoustic analysis of the fairing and compared their results to the numerical model. Some discrepancies were shown to exist. They also implemented two feedback control schemes using piezoelectric actuators. The actuators were shown to improve the damping in some structural modes but had virtually no effect on the internal acoustic field (Glaese and Anderson, 1999). Leo and Anderson used a finite/boundary element model of a fairing to try to determine the feasibility of using structural sensors and actuators (piezoelectric and proof-mass) in controlling the internal fairing acoustics. For their purely numerical analysis, the results indicate that point force and in-plane actuators are capable of achieving vibration levels commensurate to levels generated by the scaled external source (Leo and Anderson, 1998). Griffin et al. investigated the feasibility of using proof mass actuators (PMAs) to control fairing vibrations and internal acoustics. They determined that the noise reduction achieved by using PMAs was not sufficient in justifying their use, due to the added complexity of an active control system (Griffin, et al., 1999).

1.5 Is the Piezoelectric (PZT) Actuator a Feasible Choice to Control PFs?

Piezoelectric actuators are currently being considered to control the vibrations and internal acoustics of rocket PFs. There are several reasons why this is true. PZT actuators can be easily mounted or embedded into a composite PF. They also require little space and are capable of generating large forces. Lastly, they also posses the required actuating bandwidth. The following discussion ignores the structural integrity of the PZT actuator and will assume that this actuator will be able to withstand the severe stresses induced within the fairing wall during launch (PZT actuators are brittle and are prone to cracking). However, some questions about their feasibility remain unanswered:

> Does the PZT actuator have the authority to control PF internal SPLs?
> If it does, will the electrical current or power draw be excessive for the launch vehicle?

Both of these questions are not easily answered and will be the focus of this dissertation. It is the intent of this work to either answer these questions or be able to provide significant insight to the possible answer.

As was pointed out by Snyder and Hansen, “Heuristically, the best control will be achieved if the control sources are capable of “duplicating” the response of the system to the primary disturbance” (Snyder and Hansen, 1994). This implies that PZT actuators will be able to control fairing vibrations and acoustics if they are able to generate a sound field equivalent to that created by the disturbance. If they can in fact duplicate such an acoustic field, the second question above will then be considered.

Due to the PZT actuators’ electrical characteristics (capacitive), actuating a structure with these elements generally requires a large current. This may pose a significant challenge if the actuators are to be used in broadband applications. For single frequency excitation the PZT’s draw high currents, but for several frequencies being actuated at once, at some point in time, the currents will add. Some estimates of current consumption can be made for PZT patches actuating on a 12 foot diameter fairing. With a PZT (thickness, 0.4 mm) actuator covering only 1% of the fairing area, driven at 200V (amplitude) and 200 Hz, the current consumption is approximately 7.5A. If several modal frequencies (n) are to be controlled (due to the broadband excitation), then the current passing through the PZT actuator will have a value n times the current consumption passing through at a single frequency (Niezrecki and Cudney, 1996). The current demands of the actuators may be excessive for practical applications. Also, since each actuator will require two wires having a thickness dependent on the current, and a power source capable of generating the necessary current, the weight of the entire active actuator system becomes significant. The following section will discuss the approach being taken to address some of the issues raised above.

1.6 Approach and its Significance

To help determine the acoustic control authority of PZT actuators mounted onto fairing like structures, the internal acoustic response created by these actuators needs to be determined and their electrical requirements need to be investigated. To analyze this problem, an analytical model of a PZT actuator exciting a simply-supported (SS) cylinder is used to simulate the structural response obtainable by such an actuator (Lalande, 1995). In order to verify the structural model, the simulated response is compared to an experiment performed on a small-scale SS cylinder and also compared to results from finite element analysis (I-DEAS).

The analytical methods used to calculate the internal acoustic pressure of a SS cylinder have already been established. The internal acoustic response of the cylinder is determined using the spatial structural response (from the model or experiment) of the cylinder and a boundary element formulation of the Kirchoff-Helmholtz Integral (Fahy, 1985, Bullmore et al., 1986, Silcox and Lester, 1989). In order to verify the acoustic model, the boundary element formulation is compared to a derived analytical solution and also compared to an experiment performed on a SS cylinder.

The dimensions of the cylinder are then scaled such that the vibrating properties are representative of what may be encountered by an actual payload fairing. The structural response generated by the model is then used to compute the internal acoustic response of a PZT actuator exciting a large scale SS cylinder. Once the model is verified, simulations are performed for a PZT actuator exciting the cylinder at two different axial positions. A range of stiffness and damping values are considered. The results of the simulations provide a measure of the acoustic control authority of the PZT actuator. Based on the 1/3 octave-band center frequencies, an estimate of the required current for the PZT actuator is performed.

A model capable of producing accurate predictions of the sound field inside a rocket payload fairing excited by PZT actuators would require a rigorous numerical analysis of an actual fairing structure along with an extensive array of experimental measurements to be entered as parameters to the numerical model. Since we are interested in the general features of the actuating ability of the PZT actuator as applied to PFs, it should be possible predict the performance of PZT actuators and obtain results similar to what can be expected in practice.

This work contributes to the knowledge base in several ways:

1. First work that compares the analytical and finite element dynamic properties of a SS cylinder with experiment.

2. First analytical/experimental comparison of a PZT actuator model exciting a cylinder.

3. This work presents a closed form interior acoustic solution for a cylinder with a single mode response (useful for verification of numerical acoustic codes and to see how a single mode will couple with the internal acoustic modes).

4. First work that compares the analytical/experimental acoustic response of a SS cylinder and provides an empirical estimate of the acoustic loss factor within an aluminum cylinder.

5. First work that investigates the absolute sound levels a PZT actuator can generate while exciting a SS cylinder.

6. First work addressing the actuating and electrical feasibility of using PZT's to actuate rocket payload fairings.

1.7 Structural Modeling Performed on the PZT Actuation of Cylinders

The purpose of this section is to review some of the related work that has been performed on modeling PZT actuation of cylindrical structures. Several models for PZT actuator patches attached to cylinders have been presented. Initially flat plate models for PZT patches were adapted to cylinders via the Donnel-Mushtari (Lester and Lefebvre, 1991, Lefebvre, 1991) and Love shell equations (Sonti and Jones, 1991). Sonti and Jones' results showed that small patches couple better with the higher order modes of the cylinder and if a patch is too small, it is more likely to produce control spillover than point actuators. Later models were based on shell governing equations and retained the effects caused by the curvature of the actuators (Banks et al., 1992, Sonti and Jones, 1996, Lalande et al., 1994).

All of the prior models are based on force or moment inputs calculated at zero frequency excitation. None of them take into consideration the changing impedance of the structure as a function of frequency. This will lead to an incorrect response if the structural impedance changes with frequency. Impedance models of PZT actuators have been previously developed for beams (Liang, et al., 1993), plates (Zhou, 1994), rings (Rossi et al., 1993, Lalande et al., 1995) and shells (Zhou et al., 1993, Lalande et al., 1995b, Lalande, 1995). It has been shown that neglecting the frequency varying structural impedance can lead to an incorrect structural response. In this dissertation the structural response of a SS cylinder is determined using the model developed by Lalande because it incorporates the effects caused by the curvature of the actuators and the changing structural impedance of the cylinder as a function of frequency (Lalande, 1995).

1.8 Internal Acoustic Response of Cylinders

The purpose of this section is to review some of the related work that has been performed on the internal acoustic response of cylinders. Bullmore et al. modeled an aircraft fuselage as a cylinder with shear diaphragm (simply-supported) ends to evaluate the effectiveness of an active noise control system. They showed that their model could yield a structural and acoustic response that had good agreement with the measured data (Bullmore et al., 1987, Bullmore et al., 1986). Silcox et al. performed experiments on a finite closed cylinder with an emphasis to attain global noise reduction using a minimum number of actuators. They compared the use of acoustic control sources to point forces applied at the shell wall and found that the acoustic control sources require more sources but do not increase the shell structural response (as point forces do). Both methods of control were shown to be very sensitive to actuator and sensor location (Silcox et al., 1990). Silcox and Lester investigated how point force and exterior acoustic monopole actuators coupled with the structural and acoustic modes of a SS closed cylinder with rigid end caps. Their results indicate that the modal spectra for the point force actuator is modally rich and the response of the cylinder is shared equally by many cylinder modes. This implies that point force inputs would likely have significant control spillover (Silcox and Lester, 1989). Lester and Silcox also analytically compared the effectiveness of point force and PZT actuators in controlling the sound within a SS cylinder excited by an external acoustic monopole disturbance. Their results indicate there is no significant advantage in the control performance of one type of actuator over the other and that control spillover was found to limit the performance for both actuators. Increasing the size of the patch size was also found to be effective in controlling modal spillover (Lester and Silcox, 1992). Similar work performed by Lester and Lefebvre compared the effectiveness of PZTs actuating in phase (providing in-plane forces) and out of phase (providing bending moments) to control the interior sound of a closed finite cylinder. They concluded that the in-plane excitation couples better with the lower order structural modes, which ultimately couple better with the lower order interior acoustic modes (Lester and Lefebvre, 1993, Lefebvre, 1991). Lefebvre also performed a few preliminary experiments on the authority of PZT actuators on a fuselage type structure. The results imply that as the input voltage to the PZT actuator is increased by a factor of 10, the internal SPL increases by approximately 20 dB (Lefebvre, 1991). Silcox et al. analytically investigated the intensity flow between a closed SS cylinder and the contained acoustic space. An acoustic monopole was used as the disturbance while point force or PZT (in-plane) actuators controlled the internal acoustics. Their results indicate that increasing the size of the PZT actuator patch reduces the coupling between the actuator and the higher order modes (reducing control spillover) and there was no significant advantage of one actuator over the other. Also, the regions of the cylinder away from the primary disturbance were shown to contribute more to the inward intensity flux (Silcox, R. J. et al., 1993).

1.9 Overview of Dissertation

Initially the theoretical formulation of Lalande’s impedance model of a PZT actuator exciting a SS cylinder is reviewed in chapter 2. The creation of a simply-supported boundary condition on an actual cylinder is also described. The experimental results for the created cylinder are then presented and compared to the impedance model and finite element analysis results. In chapter 3 a review of the theory required to obtain the internal acoustic response of the cylinder along with a derivation of a closed form solution to the acoustic response for a single structural mode is described. Verification of the numerical acoustic model is presented in chapter 4. To verify the boundary element model of the internal acoustic response of the cylinder, an experiment is conducted to compare the experimental SPLs within the cylinder to that predicted by the model. The experiment conducted and the determination of the acoustic loss factor are described. In chapter 5, the authority of the PZT actuator as applied to a SS cylinder which emulates an actual fairing is discussed. The electrical requirements for the PZT actuator in this application are also addressed. In chapter 6 some practical considerations in controlling fairing vibrations and internal acoustics is briefly considered, followed by conclusions and recommendations in chapter 7.